

Electricity Intensity Patterns for New Zealand, Selected Countries and World Regions

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ABSTRACT

This paper investigates the patterns of electricity intensity, electricity intensity curves and electricity intensity factors for New Zealand, as well as for selected countries and various regions of the world. The period chosen is that from 1980 to the present, before and through the period of recent electricity reforms, restructuring and de-regulation. In general the patterns over time are smooth regardless of the size of the society under consideration. They appear uninfluenced by the adoption of regulatory or market type economies and their promotion through political direction. The link between economic performance and electricity consumption is stronger in developing countries than for industrialized countries.

1. INTRODUCTION

Electricity is one of the most dominant forms of energy in human society. Its flexibility as an energy carrier has increased its share in total energy consumed in many countries. This has accelerated the economic and social wealth in those countries, through technological innovation and adoption, and increased industrial production of physical goods and services. This paper investigates the patterns of electricity intensity, electricity intensity curves and electricity intensity factors for New Zealand, selected countries and regions of the world, from before and through the period of recent electricity reforms, restructuring and de-regulation.

2. ELECTRICITY INTENSITY

Electricity intensity is one measure of how electricity is consumed in an economy. It is the ratio of the amount of electricity, measured in GWh, used in generating the industrial production, measured in monetary terms by the gross domestic product (GDP), of a country. Its variations over time can be helpful in determining the directions both an economy and electricity development is pursuing. It is expressed as [1],

$$EI = \frac{\text{Consumption}}{\text{GDP}} \quad (1)$$

A number of underlying factors are reflected by changes in the ratio, such as the state of technology, the price of electricity, the composition of GDP, the levels of activity in individual electricity user sectors, and demographic and sociological factors. Although it is believed that economic growth and electricity demand are linked, the strength of the relation is different from region to region and depends on the stage of development of a region. A number of reasons may exist for changes in electricity intensity within a particular sector of industry. They include the growth or decline of electricity-specific end-uses, changes in their efficiency, increases in the use of electricity at the expense of other fuels, or the development of new electricity technology.

EI patterns are seen to be limited in their predictive capability. They are strictly a measure of how an economy uses electricity in its development. An alternative representation which includes the social impact is an electricity intensity curve (EIC). This shows the relationship between EI and the level of average personal wealth in a country as measured by GDP per capita. The slope of the curve may assist in determining whether the electrical industry is in a growth, mature or ageing phase. It can give a more predictive indication of economic development due to electricity use, and its consequent benefit to society through wealth creation.

Each point on the EIC represents a combination of consumption, GDP and population for a particular year. This is called the electricity intensity factor (EIF). These points can be graphed against time. A peak in this graph is a strong indication of a more subtle inflexion in the EIC. The EIF is defined as,

$$\begin{aligned} EIF &= \frac{\text{Consumption} / \text{GDP}}{\text{GDP} / \text{Population}} \\ &= \frac{\text{Consumption} \times \text{Population}}{\text{GDP}^2} \quad (2) \end{aligned}$$

This paper investigates these patterns for selected countries and regions of the world. The selected countries for this study are Brazil, China, France, Germany, India, Indonesia, Japan, Maldives, New Zealand, Russia, United Kingdom, and the United States.

Apart from New Zealand and the Maldives, all the other countries are selected on the basis of having the largest populations, economies or electricity consumptions. The Maldives represents a relatively small developing economy.

The world data is divided into eight regions. They are North America (industrialized), Central and South America, Western Europe (industrialized), Eastern Europe and the Former Soviet Union (FSU), Industrialized Asia, Middle East, Africa and developing Asia.

3. ELECTRICITY CONSUMPTION AND INTENSITIES IN NEW ZEALAND

The electricity consumption for New Zealand from 1943 to 1999 is shown in Figure 1. The electricity consumption data are divided into Domestic and Non-Domestic sectors. There is an increase in trend in the consumption data for all the sectors. In terms of larger trend changes, the rate of consumption growth is generally very slow in the Domestic sector especially from 1975 onwards.

The patterns have been relatively smooth, despite the amendments, reforms and changes associated with deregulation, or any of the myriad of factors that might be considered as influences. Price variation, one of the major reasons deregulation was introduced, has had no long term effect on the patterns.

Figure 2 shows the electricity per capita, electricity intensity, electricity intensity curve, and electricity intensity factors for New Zealand from 1980 to 2002. The per capita electricity consumption has increased except in the last few years. The electricity intensity has peaked around 1991 and has been declining in the latter years. The electricity intensity curve is similar, indicating that the electricity industry in New Zealand has gone through the early phase of growth, matured and is now in the ageing phase. The electricity intensity factor in New Zealand has decreased over the entire period indicating a reduction in intensity per unit of wealth creation. Electricity is declining in importance relative to the generation of economic wealth.

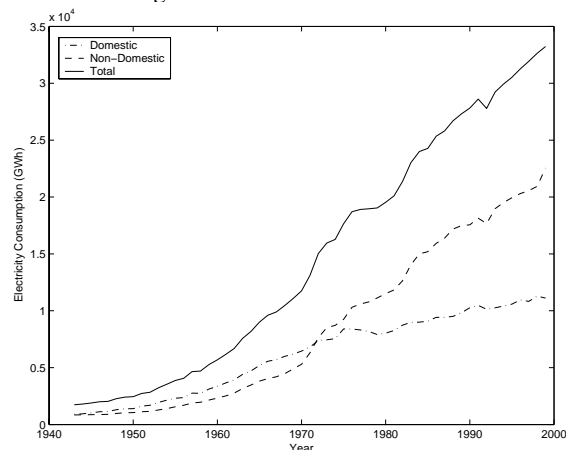


Figure 1 Electricity consumption in New Zealand

4. ELECTRICITY INTENSITIES IN SELECTED COUNTRIES OF THE WORLD

The relationships between electricity consumption, GDP and population of 12 selected countries were

investigated. Figure 3 shows the electricity consumption per capita for these countries. This is highest in the United States while New Zealand consumes the second highest amount of electricity per person. The electricity consumption per capita in the industrialized countries of the United Kingdom, Japan, Germany, France and Russia are very similar. The electricity consumed in the developing countries is very low compared to the industrialized countries.

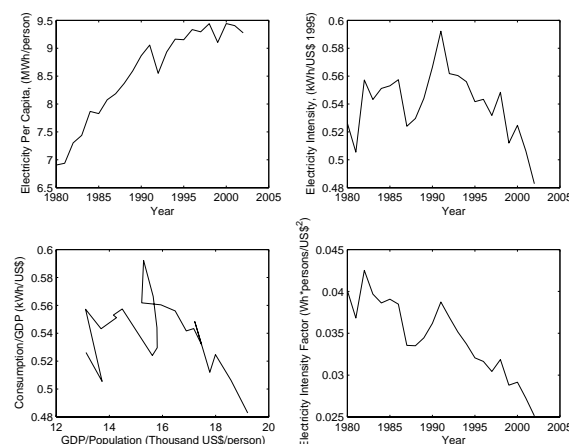


Figure 2 Electricity per capita, intensity, intensity curve and intensity factors for New Zealand

Figure 4 shows the GDP per capita for the 12 countries. Japan shows the highest GDP per capita of the 12 countries presented. The GDP per capita for United States, Germany and France are next with United Kingdom and New Zealand showing very similar patterns throughout the period. The GDP per capita for the developing countries are the lowest.

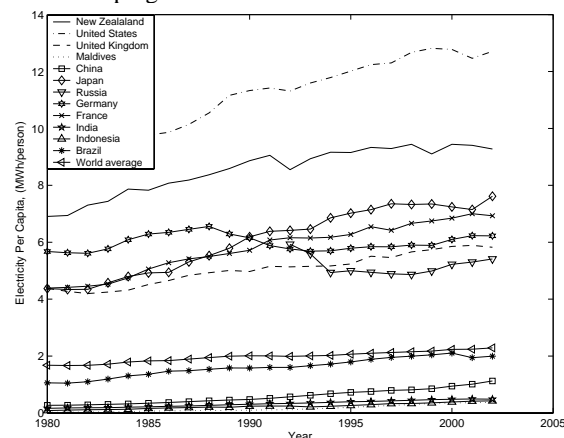


Figure 3 Electricity per capita for the 12 countries

Figure 5 shows the electricity intensity in these countries. The electricity intensity is highest in Russia.

China and India are next. New Zealand has the fourth highest electricity intensity throughout the period. For the other countries, the difference in electricity intensity is small, although Indonesia has had a large variation over the period.

The Electricity intensity curves for the 12 countries are shown in Figure 6. The curves are spread out along the two axes. There is a distinguishing pattern in the curves of the industrialized countries and the developing countries. The industrialized countries with high income per capita generally have relatively constant low consumption per dollar of GDP. The developing countries with low, relatively constant, income per capita, have low to high levels of consumption per dollar of GDP. The electricity intensity factors for the industrialized countries are shown in Figure 7.

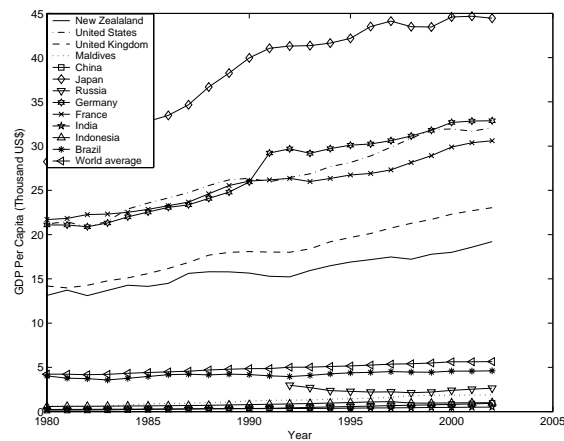


Figure 4 GDP per capita for the 12 countries

In general, the electricity intensity factors for the industrialized countries have decreased over time. The electricity intensity factors for New Zealand are the highest over the whole period, while the United States and the United Kingdom have similar levels to each other. Japan shows the lowest electricity intensity factors.

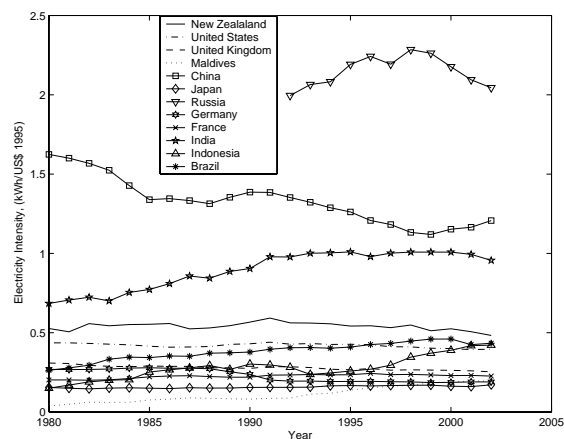


Figure 5 Electricity intensity in the selected countries

The sudden drop in electricity intensity for Germany from 1992 is because electricity consumption data for Germany after 1992 includes those for West and East

Germany. However the GDP data for East Germany prior to 1992 was

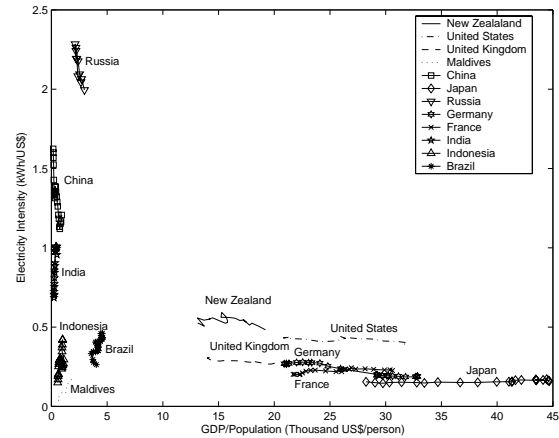


Figure 6 Electricity intensity curves for the selected countries

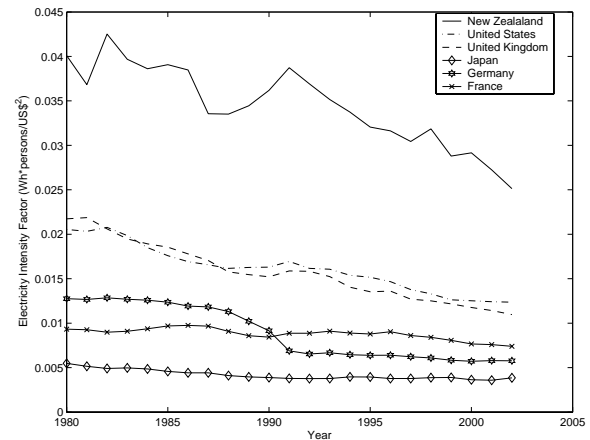


Figure 7 Electricity intensity factors for the industrialized countries

not available. Therefore, the GDP data for Germany before 1992 is less than it should have been due to the unavailability of this data. Overall, for the industrialized countries the electricity intensity factors are converging.

The electricity intensity factors for the developing countries are shown in Figure 8. In China, the EIF has decreased dramatically. In India, the factor has decreased slightly over the years. Overall the electricity intensity factors appear to be converging in a similar manner to those for the industrialized countries, but to a much higher level.

The electricity intensity, and thus the electricity intensity curve and electricity intensity factors, is higher for New Zealand than the other industrialized countries. The high electricity intensities in some countries have been explained with regard to availability of inexpensive hydro capacity [2]. Hydroelectricity accounts for 55% of the total electricity generated in New Zealand whereas the next competing industrialized country, France, has only 14% of its total electricity generated using hydropower.

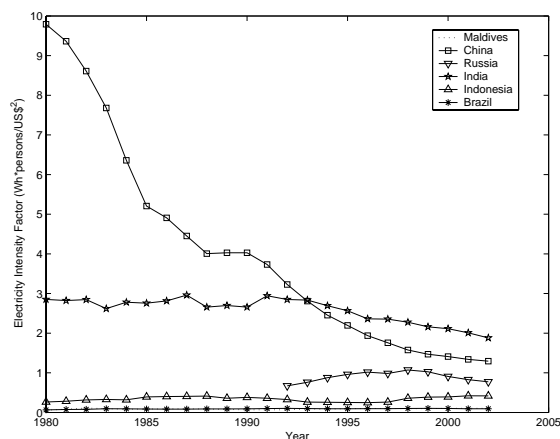


Figure 8 Electricity intensity factors for the developing countries

On the other hand the other industrialized countries have a significant percentage of nuclear, whereas the developing countries have little. Perhaps as China and others develop, this energy source may be used further.

The high electricity intensity in New Zealand relative to other industrialized nations may also be the result of high electricity consumption in residential homes. In general, electricity is used for all residential purposes including water heating, air conditioning and cooking. In many of the developed countries natural gas is used for water heating, room heating and cooking. It may also be due to the electricity intensive industries (EIIs) such as aluminium smelter, steel and pulp, and paper mills.

Electricity prices and relative fuel prices play an important role in locating electricity intensive industries, and the choice of energy carrier and space heating [2]. However it has been found that the electricity price does not affect electricity efficiency significantly in the household and service sectors [2]. This was supported by the fact that the energy intensities in several countries have continued to decrease when energy prices have been falling.

5. WORLD REGIONAL ELECTRICITY PATTERNS

The world total electricity consumption is shown in Figure 9. The pattern is smooth and increasing, indicating that it can be modeled independently from all factors other than time.

Figure 10 shows the electricity consumption in the eight regions of the world from 1980 to 2002. North America consumes the highest amount of electricity throughout the period and at 2002 this region accounts for about 30% of the world electricity consumption. Developing Asia shows the highest rate of growth and by 2002 this region is the second highest electricity consumer. Eastern Europe and the Former Soviet Union show recovery from the economic and social declines of the early 1990s. Africa and the

Middle East consume the smallest amounts of electricity. The low electricity consumption in Africa with 14% of the world population indicates the low level of electrification in some countries of this region. In general the electricity consumption in the industrialized countries is increasing at a slower rate than those in the developing world.

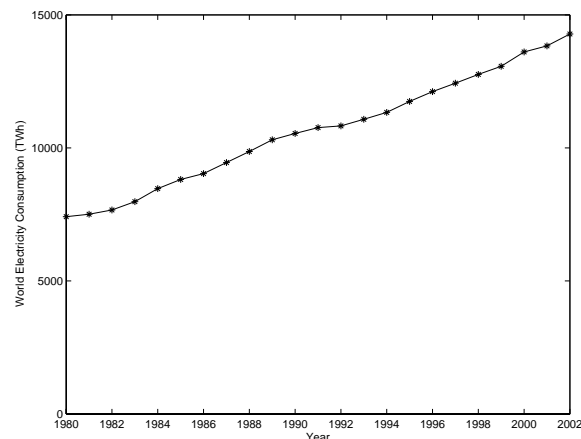


Figure 9 World Total electricity consumption from 1980 to 2002

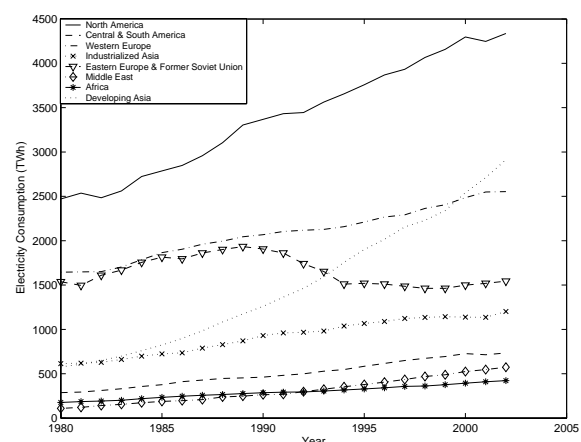


Figure 10 Electricity Consumption in the World (8 regions)

6. ELECTRICITY INTENSITY IN THE REGIONS OF THE WORLD

Figure 11 shows the electricity consumption per capita for the regions of the world and the world total. The electricity consumption per capita is the highest for North America. The per capita electricity consumption has gradually increased for all regions except for Eastern Europe and the Former Soviet Union. This is mainly affected by decreases in electricity consumption due to the fall of the Soviet regime, the highest electricity consumer in this region. The per capita electricity consumption is the highest for the industrialized regions.

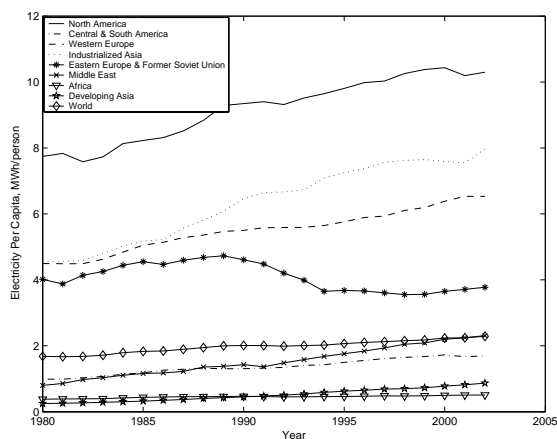


Figure 11 Electricity per capita for the regions of the world and world total

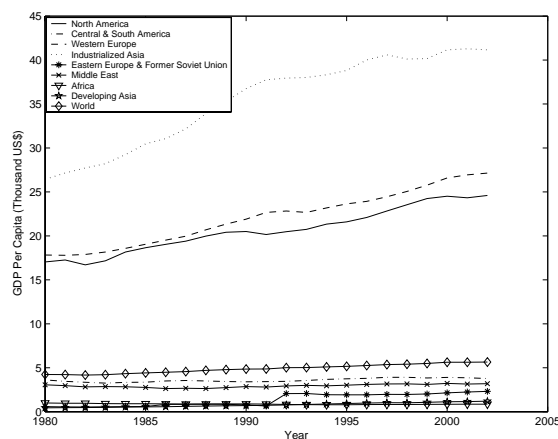


Figure 12 GDP per capita for the regions of the world and world total

Figure 12 shows the corresponding per capita GDP for the regions. The wealthiest region is not necessarily the most energy intensive. Industrialized Asia has the highest GDP per capita but it has got the second highest electricity consumption per capita. The high GDP per capita is due to that of Japan as compared to Australia and New Zealand in this region.

Figure 13 and 14 show the electricity intensity for the regions of the world and the world total. The electricity intensity in Eastern Europe and the Former Soviet Union is the highest and most varying. There is a sudden decrease in the early 1990s reflecting the break up of the Soviet Union and its transition from a centralized planned system towards a more free market economy. However, even after the fall of the Soviet regime, this region has still got the highest electricity intensity with a decreasing trend.

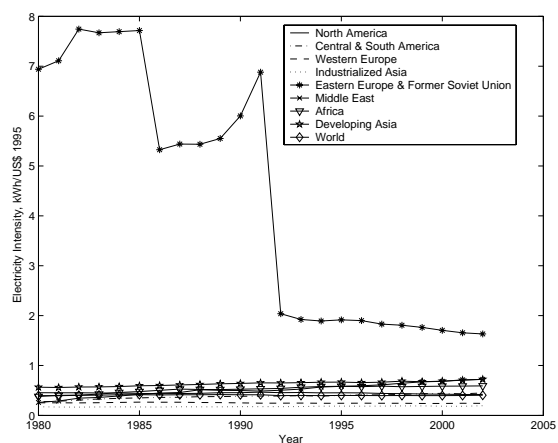


Figure 13 Electricity Intensity for the various regions of the world

The developing regions of the world reflect an increasing intensity over the years. The fastest growth is observed in the Middle East. Irrespective of these trends, the world average electricity intensity has been at a near constant level of around 0.4 kWh/US\$ (1995) for more than 20 years, reflecting the dominance of Industrialized Asia, Western Europe and North America which display very constant levels over the period.

The electricity intensity curves for the regions of the world are shown in Figure 15.

A significant gap between the income levels of industrialized regions of the world and the developing world can be observed. The intensity curves for North America, Western Europe and Industrialized Asia are almost horizontal indicating that the economic wealth is achieved without changes in electricity intensity. By

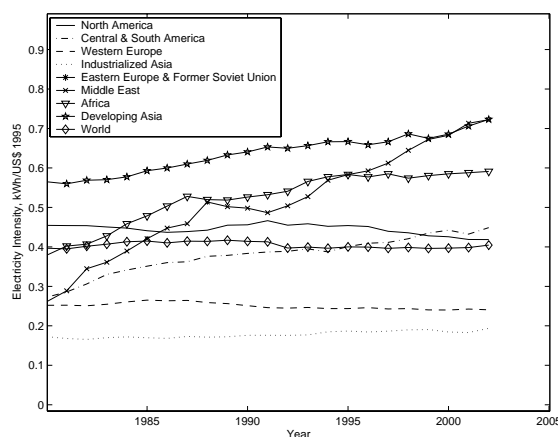


Figure 14 Electricity intensity for the regions (Figure 13 enlarged)

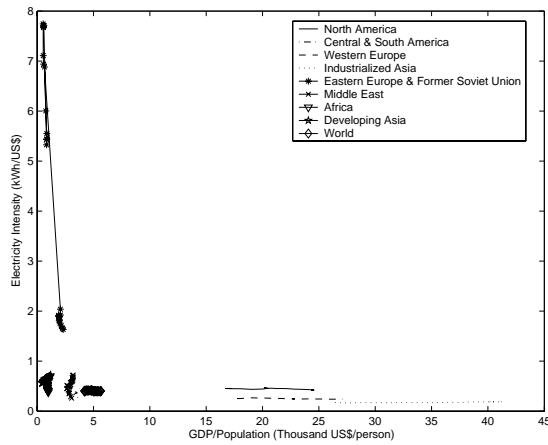


Figure 15 Electricity intensity curves for the regions

contrast, in the developing regions, the per capita GDP is nearly constant and is independent of electricity intensity. The curve for Eastern Europe and the Former Soviet Union is much higher than all the rest. The world average reflects the industrialized regions being horizontal with relatively low values of EI for low wealth per person.

The electricity intensity factors for the regions of the world are shown in Figure 16. Eastern Europe and Former Soviet Union has the highest intensity factor which is rapidly decreasing. The electricity intensity factors for Africa and Developing Asia appear to be converging to a similar level. The intensity factors for the industrialized regions are very low, comparable to each other and at very constant levels over the years. The intensity factors for all the developing regions are above the world average while those for the industrialized regions are below the average.

Although the developing countries account for more than 75 percent of the world population, the electricity consumption in these countries is only one-third of the world's electricity consumption [3]. The developing countries are expected to have a robust economic growth in the coming years. This requires access to reliable supplies of electricity. As a result, various strategies have been implemented such as privatization to increase investment in the electricity industry and enacting government policies to encourage investment from potential foreign participants [3]. In addition, rural electrification schemes are expected to be introduced both to improve the standard of living and to increase the productivity of rural communities. The growth in electricity consumption in the industrialized world is expected to increase more slowly. The mature electricity sectors and gains in equipment efficiency in the industrialized countries are expected to slow down the growth in electricity consumption.

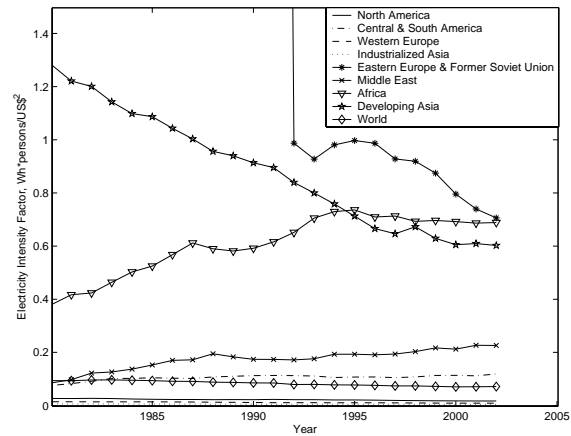


Figure 16 Electricity intensity factors for the regions of the world

7. CONCLUSIONS

This paper has investigated the patterns of electricity consumption in New Zealand, selected countries, and regions of the world. The relationship between economic growth and electricity consumption has been investigated using electricity intensity, electricity intensity curves, and electricity intensity factors. The link between economic performance and energy demand is strongly influenced by the stage of the development and the standard of living in a given region. The link between economic growth and electricity consumption is stronger in developing countries than those for industrialized countries. In the developing countries, the economies grow as more new industries that generally contribute to economic wealth emerge. In the industrialized countries, although the electricity consumption remains high, electricity use is more stable or slowly changing. In addition, the chances for increased efficiency, due to replacement of old equipment with modern equipment, in the industrialized countries are higher than those for the developing countries. This has contributed to a reduction in the energy intensity of the industrialized countries. A general trend of a decreasing intensity in the industrialized countries and increasing intensity in the developing countries has also been observed.

8. REFERENCES

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